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A DOWN-THE-ROW SPOT SPRAYER

ARS W-50
November 1977

WESTERN REGION

AGRICULTURAL RESEARCH SERVICE • U.S. DEPARTMENT OF AGRICULTURE

ABSTRACT

P. A. Boving. A Down-The-Row Spot Sprayer. U.S. Department of Agriculture, Agricultural Research Service ARS W-50, 7 pp., September 1977.

A prototype spot sprayer was constructed that will successfully treat row-seeded plants at rates of 600 to 700 individual plants per minute. The infrared sensor system detects objects 3/16 inch (5 mm) high and 1/64 inch (0.5 mm) thick. The signals are fed to delay circuits, which permit the spray nozzle to operate behind the sensor field of view. Cost for the sensor and delays is about $225 per row, based on small quantity orders. Although the sprayer performs satisfactorily on rows of plants where the foliage has not grown together, it treats the first plant of a series where the foliage has intermeshed.

KEYWORDS: spot sprayer, seedling treatment, transplant treatment, delay timing, infrared sensor, spot treatment, nonbroadcast application, selective spraying.

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A DOWN-THE-ROW SPOT SPRAYER

By P. A. Boving[1]

BACKGROUND

When seeded crops emerge, or transplants are set out, their ground coverage is small. If chemicals are sprayed on these plants with conventional broadcast or band-spray equipment, much of the sprayed material is wastefully deposited on the ground where it becomes a potential source of pollution. Fulgram et al.[2] found that they could save 60 percent of the spray materials by treating individual cotton plants rather than by broadcast spraying. The plants were sensed with a wire probe, which, when deflected, operated a snap action switch to control an electric spray valve. Wilborn[3] reported on a spot sprayer for treating weeds growing above the crop by sensing their presence electronically and spraying the weed only. D. L. Reichard (personal commun.) has used pneumatic sensing and delays for controlling a spot sprayer. Reuschenbach[4] also reported on pneumatic sensing of plants in rows.

Statement of the Problem

In the Yakima area, sugarbeet seed is precision planted to obtain a plant every 3 to 4 inches (7.6 to 10.2 cm) in the row. As the plants mature, they are thinned to produce a mature root every 12 inches (30.5 cm). The sugarbeet plant is attacked by insects from the time of emergence. Insect attacks result in reduced sugar yield and an increase in sugar extraction costs. Treatment of emerging seedlings for protection from insects helps to maintain yields and keep production costs down.

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[2] Fulgram, F. E., Wooten, O. B., and Williford, J. R. Equipment for applying partial bands in cross-plowed cotton. Paper presented at 25th Annual Meeting, Southern Weed Sciences Society, Dallas, Tex., January 1972.

[3] Wilborn, E. Spraying innovations to help you. Progressive Farmer, p. 15, March 1972.

[4] Reusenbach, H. Pneumatic systems for the non-contract scanning of plants. Proceedings of CIGR (Commission Internationale du Genie Rurale) 74-III-103, Paris, France. 1974.

Using broadcast techniques to treat seedlings with pesticides is very inefficient when the ground coverage of the crop is 10 percent or less. Spraying only the crown of each plant would result in savings in material applied, increased application efficiencies, reduced costs to the grower, better protection from insects, reduced harm to the biosphere, and reduced soil compaction caused by heavy equipment loads. Spot spraying of individual plants can also be used to protect transplanted crops from insects in the Midwestern and Eastern United States.

Operational Parameters

To determine the response time for a solenoid-operated nozzle, the time required for the leading edge of a spray pattern to pass plant canopies 3 inches (7.6 cm) and 12 inches (30.5 cm) wide was computed for three different sprayer speeds, as shown in table 1. At a speed of 2 mi/h (3.2 km/h), which is considered to be a practical speed for operating multiple-row equipment in a precision-planted crop, a spray nozzle would be required to treat seedlings spaced 3 inches (7.8 cm) apart in the row at a rate of 70 seedlings per minute.

To avoid injury to tender plants, a sensing device used to control nozzle operation should not make physical contact with the plant. An interrupted light beam would satisfy this requirement. The sensor should not be affected by sunlight or dust and should be mounted on a floating carriage or sled to provide height control required for operation close to ground. All electrical components should operate on 12 to 14 volts d.c., which could be taken from the tractor battery. Finally, the spray nozzle should function at some distance behind the sensor to prevent sprayer dust from interfering with the light beam. This calls for a signal delay system. The times in table 2 were calculated to determine the desired delay interval.

TABLE 1.--*Time needed to pass the canopy of a plant for selected forward speeds*

Forward speed (miles per hour)	Time to pass canopy when size of object crossed is--	
	3 inches (7.6 cm)	12 inches (30.5 cm)
	Milliseconds	
5 (8.0 km/h)	28	
0.5 (0.8 km/h)		1,370
2 (3.2 km/h)		300

TABLE 2.--*Delay times required to operate a spray nozzle at a distance behind the sensor for given forward speeds*

Distance from sensor to nozzle (inches)	Delay times for the following forward (ground) speeds, in miles per hour		
	2 (3.2 km/h)	2.5 (4 km/h)	3 (4.8 km/h)
	----------------*Milliseconds*--------------		
3 (7.6 cm)	85.5	68.2	56.8
6 (15.2 cm)	170.8	136.5	113.8
9 (22.9 cm)	256	205	170.4
12 (30.5 cm)	342.5	273	227

A 200-millesecond delay would satisfy a nozzle-to-sensor spacing of 7 inches (17.8 cm) at 2 mi/h (3.2 (km/h), 9 inches (22.9 cm) at 2.5 mi/h (4 km/h), and 10 inches (25.4 cm) at 3 mi/h (4.8 km/h). A spacing of 10 inches (25.4 cm) can be expected to contain three or four plants. Therefore, at least four delay circuits will be required to handle the maximum number of signals possible without missing any plants with the spray.

INITIAL ASSEMBLY

An infrared optical source and sensor[5] were purchased that could detect an object 0.004 inch (0.1 mm) thick when the source and sensor are spaced 10 inches (25.4 cm) apart. The same supplier also manufactured delay circuits[6] compatible with the sensor, and four of these were purchased. These delays were equipped with control circuits as well as trigger circuits so that the delays could be coupled in cascade; that is, when one delay is engaged, the next signal will be routed to the next unemployed delay. The outputs of these delay circuits were connected to a relay controlling a solenoid valve.

Preliminary Tests

Sensor and delays.--Without the ability to precondition the delays, the first signal triggers a random number of delays. This problem was overcome by using a four-step rotary counter (fig. 1). Each step of the counter controls one section of a four-channel electronic switch or gate so that the signal is fed to only one delay at a time.[7] The counter is stepped by the trailing edge of the signal, so that the next signal is fed to the next delay. Each delay operates on every fourth signal pulse; all other signals are blocked by the switch or gate. The rotary counter sets itself when the power is turned on, choosing any one of the four positions, and the signal from the sensor advances the counter one step for each signal pulse.

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[5] Opcon 1100 sensor and 1204 detector fitted with 45° mirrors and diaphragm with a 1-mm aperture in the sensor. Opcon Inc., 720 80th Street, S.W., Everett, Wash. 98203.

[6] Opcon 8323A dual 1-shot module.

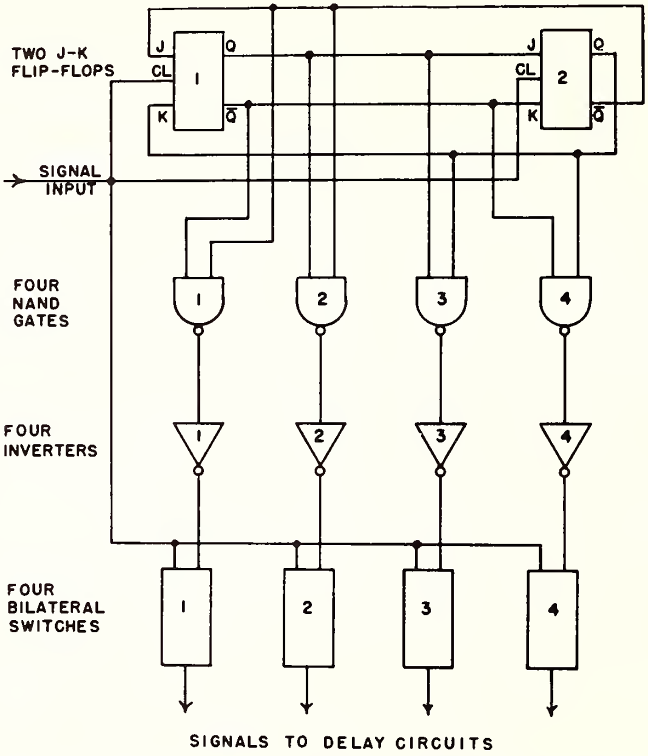

Figure 1.--Circuit diagram of rotary counter and switch for routing signals to delay circuits.

Solenoid valve.--Good flow control and satisfactory operation were obtained at pulse rates as high as 900 cycles per minute with a Skinner B2 LX 127 solenoid valve.

Hydraulic nozzles.--Initial tests were conducted using a hydraulic nozzle pointed straight down. The nozzle was connected to the solenoid valve with a 4-inch (10.2-cm) long downpipe. This nozzle dripped between spray cycles due to trapped air and produced coarser spray drops than desired. It was replaced with a Binks Air-Brush with the reservoir modified to prevent siphoning when the nozzle was aimed straight down. The solenoid valve controlled the compressed air supply to this nozzle, which produces a solid cone pattern of fine drops when operated at 25 to 40 pounds per square inch. Water soluble dyes or diluted fluorescent tempera paints were used in all tests. A schematic diagram of the unit is presented in figure 2.

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[7] Radio Corporation of America. COS/MOS Integrated Circuits Manual. REC Technical Series CMS-271. 1972.

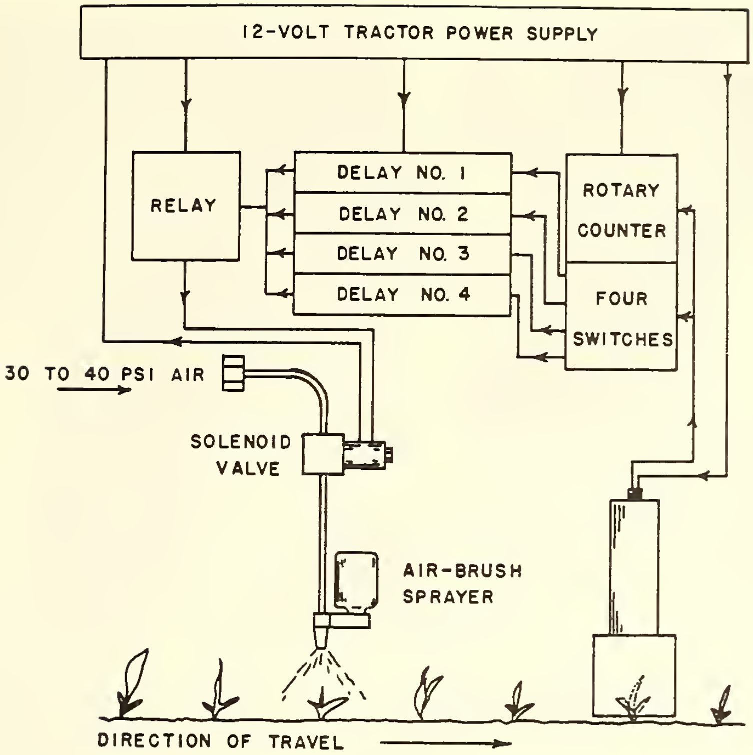

Figure 2.--Block diagram of sprayer.

Sensor carriage.--A two-wheeled carriage was constructed to control the height of the sensor above the ground surface. It was pivoted on a 1-3/8- by 5/8-inch (3.5- by 1.6-cm) steel upright member, which could be attached to a tractor implement bar like a tool shank. Self-cleaning planter press wheels were used to give the sensor a firm platform. For shop testing, the carriage was fitted with a temporary third wheel to steady the unit. The upright member controlled the vertical position of the sensors, and a unit frame maintained their alinement with each other. The spray nozzle was also mounted on the carriage to fix the spacing between the sensor and the nozzle. The completed prototype is illustrated in figure 3.

Shop testing.--A 12-ft (3.7-m) length of steel angle laid on the floor served as a test track. The carriage wheels rested on the horizontal portion and rubbed against the upright portion of the angle for guidance. A wooden plank with a series of 10-d nails spaced about 3 inches (7.6 cm) apart represented a row of plants. Adding machine paper strips were placed alongside the nails so that the location of the spots produced by the sprayer could be compared to the nail location to determine the accuracy of spray placement. The delays were all adjusted to about 200 ms, and the nozzle was located 7 inches (17.8 cm) behind the sensor. The sensor detected an object standing 3/32 inch (3 mm) higher than the underside of the sensor housing.

Endurance tests were conducted on the electronic circuit by holding the carriage stationary and interrupting the light beam about 350 times per minute. After three 4-hour tests, the components were still functioning as designed.

In the final shop test, the sensor unit was mounted on a tractor tool bar and tested on an asphalt surface, using the plank and a paper tape strip to

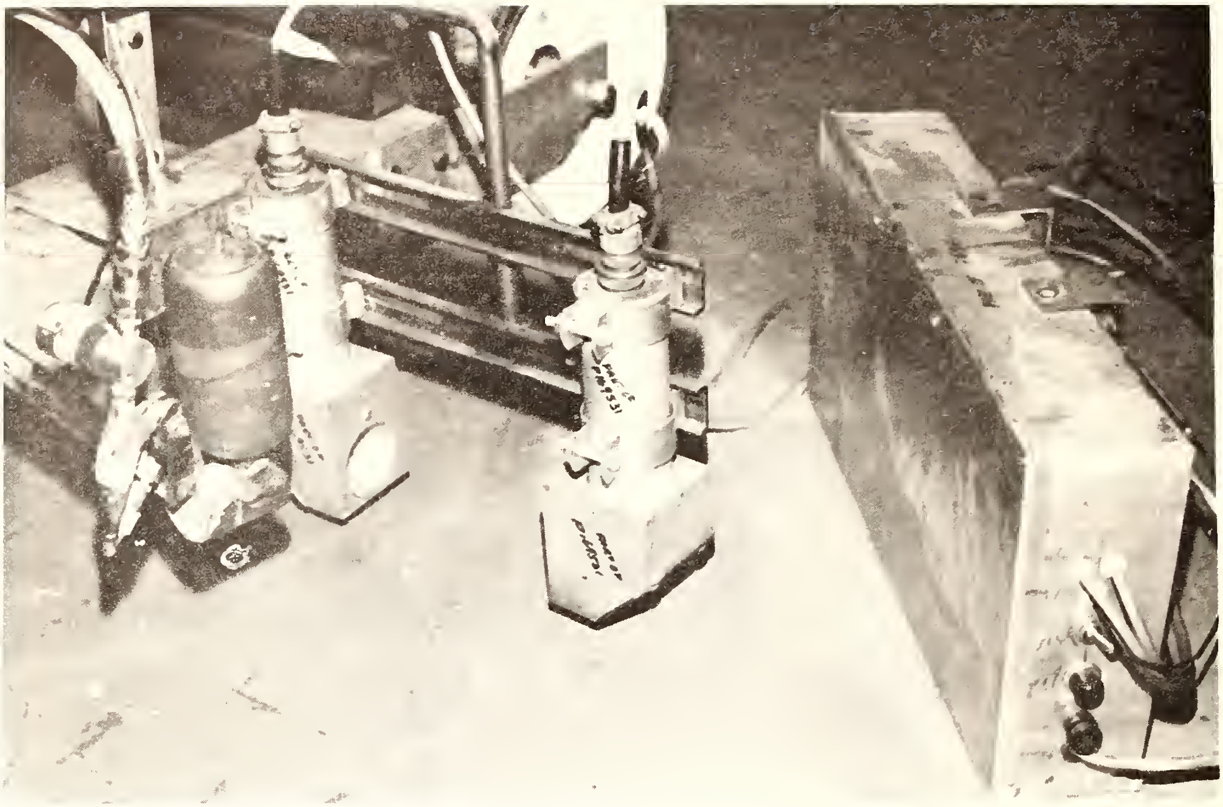

Figure 3.--Prototype sprayer showing, left to right, modified air spray nozzle with reservoir, infrared sensor and source, and box containing electronic circuits. Part of the carriage is shown in the left background.

determine the maximum ground speed for satisfactory spray operation. The tractor was allowed 50 ft (15 m) of asphalt surface to stabilize its speed before the sensor detected the first nail in the plank. Maximum speed, before overloading the circuit and delays (indicated by skips in the spray record), was 2 mi/h (3.2 km/h) or a treatment rate of 700 to 720 plants per minute.

Field Test

The sprayer was tested on a single row of spinach plants in October 1974. The plants were seeded at a spacing of 3 to 4 inches (7.62 to 10.2 cm). The condition of the crop varied from single plants 1/2 inch to 2 inches (1 to 5 cm) high with frequent skips to plants 4 to 6 inches (10 to 15 cm) high where the foliage was continuous in the row. This crop was advanced beyond the stage of growth for which the sprayer was originally intended. The sprayer treated all single plants in the row where the foliage was not continuous; however, for sections of the row where the foliage from several plants was continuous, only the first plant was treated. The row averaged 600 to 625 plants in 300 ft (100 m) of row, and estimates of sprayed material used were less than 10 ml to treat these plants. A tractor speed of 1-3/4 to 2 mi/h (2.8 to 3.2 km/h) was used to treat 600 to 700 plants per minute.

CONCLUSIONS

Although the prototype machine has performed exactly as designed, a more advanced delay system will be required in fields where leaves from a few plants have begun intermeshing. Research is, therefore, continuing on a more advanced delay system that will control the spray nozzle to treat the area over which the infrared beam has been blocked, rather than the initial edge of the blocked area in the present control system.

☆U. S. GPO: 1978—792-931

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